A Cooporative Analysis Framework for Investment Decisions in Community Source Partnerships

Manlu Liu  
*University of Arizona, manluliu@email.arizona.edu*

Daniel D. Zeng  
*University of Arizona, zeng@email.arizona.edu*

J. Leon Zhao  
*University of Arizona, jlzhang@email.arizona.edu*

Follow this and additional works at: [http://aisel.aisnet.org/amcis2008](http://aisel.aisnet.org/amcis2008)

Recommended Citation  
[http://aisel.aisnet.org/amcis2008/278](http://aisel.aisnet.org/amcis2008/278)
A Cooperative Analysis Framework for Investment Decisions in Community Source Partnerships

Manlu Liu  
The University of Arizona  /manluliu@email.arizona.edu  

Daniel D. Zeng  
The University of Arizona  /zeng@email.arizona.edu  

J. Leon Zhao  
The University of Arizona  /jlzhao@email.arizona.edu  

ABSTRACT

Community source development has emerged as a new way of developing enterprise applications, leading to a unique type of open source practice involving partnership and investments from multiple organizations. A critical research question in community source development is concerned with the rationale and the economic incentives behind investments from partnering organizations. In this paper, we examine a real world case, the Kuali community source project, and propose a cooperative decision framework to analyze investment decisions made by various types of organizations involved in community source. We analyze joint investment decisions and adopt the Black-Scholes model to capture individual organizations’ decision-making in risky environments. Our analytical results are able to explain an array of observed investment behavior from community-source partners and reveal useful insights to help these organizations make decisions. Our results also facilitate a general understanding of the emerging community source development landscape.

Keywords  
Decision-making, decision analysis, community source, Black-Scholes model, Kuali case, open source

INTRODUCTION

A community source project is “an open source project that requires significant investments from institutional partners in both human resources and cash contributions” (Liu, Wang, and Zhao, 2007). The community source approach provides a viable alternative to vendor-provided packaged solutions by combining effectively the benefits of in-house development and outsourcing. One critical decision for prospective community source partners is whether or not it should pay a significant amount of partnership fee to join the development community, which we refer to as “the community source investment decision” or “the community partnership decision.” As in general, the resulting software package of a community source project is available as an open source free or charge, it seems counter-intuitive for an organization to be willing to make major investments. Yes, as shown in many real-world examples, many organizations have already invested heavily in various kinds of community source projects. This poses an interesting and timely research challenge as to gaining an in-depth understanding of economic incentives behind these decisions and further developing an actionable decision framework for the community partnership decisions.

The main research question to be examined in this paper is “why an institution should join a community source project as a paying development partner and how related investment decisions should be made.” We start our investigation by analyzing a real world project named Kuali, a community source project targeting at a reusable academic ERP system, with around twenty university partners in 2007. Several derivative research questions to be examined include what are the costs and benefits of becoming a partner of the community source project and under what conditions an institution might be more willing to become a development partner.

The modeling approach adopted in our study is cooperative decision analysis, with an emphasis on interacting behavior among institutions. Decision-making in community source is challenging since the success of community source project is affected by many factors. For example, successful collaboration among multiple partners plays an important role in the level of accomplishment of community source projects. The Black-Scholes model is used in the payoffs functions for each institution. The Black-Scholes model was developed to capture the randomness in the stock market and the valuation of real
options; as such, it is suitable for analyzing investment decisions in community source. To conduct analytical analysis, the values we use for the parameters in Black-Scholes model is based on observing the Kuali case. The main intended contribution of our research is to formulate the community source partnership decision analytically and derive formal properties and simulation-based insights to gain insights about various interesting investment behavior observed in emerging community source practice, and in turn help the organizations make related decisions.

The remainder of paper is structured as follows. In Section 2, we briefly review literature on open source software development and related background on the Black-Scholes model. In Section 3, we introduce the Kuali case as a community source project and discuss some interesting empirical findings. In Section 4, we apply cooperative decision analysis to the community partnership decision problem and derive several propositions. Finally, we outline our research contributions and future research directions in Section 5.

LITERATURE REVIEW

Our modeling work builds on the literature in open/community source, decision analysis and option pricing models.

Open /community Source

Community source is a recent trend for organizations to develop the system. The literature in community source is very limited. Liu, Wang and Zhao (2007) observed the flexibility issue in community source. Liu and Zhao (2007) applied real option analysis in community source. Since the system will become open source eventually in community source, we can see that community source is a unique form of open source. Open source software (OSS) development has attracted lots of research interest in recent years. Robert et al. (2006) conducted a longitudinal field study in the Apache projects and revealed how different motivations of OSS developers are interrelated, how these motivations influence participation leading to performance, and how past performance influences subsequent motivations. Fitzgerald (2006) contended that open source software phenomenon had metamorphosed into a more mainstream and commercially viable form, which was labeled as OSS 2.0. One of the main characteristics in OSS 2.0 is focusing on leveraging community software development.

Decision Analysis

Decision analysis approaches have been used in IS field in the last decade (Kimmle 1972, King et al. 1975), and much progress has been made in recent research. Robert (2003) applied cooperative game theoretic models for decision-making in contexts of library cooperation. Ekstrom et al. (2005) construct a real options model to measure the value of flexibility in IT investment and use a decision analysis model to evaluate the value of the pilot project. Thomaidis et al. (2006) presents a fuzzy multi-criteria decision-making approach to the evaluation of IT projects.

In this paper, we apply a cooperative decision analysis framework for the community partnership decision. This type of analysis is different from a full-fledged strategic decision analysis based on game-theoretic frameworks, where decisions from involved parties are inherently intertwined and can only be made jointly through various equilibrium concepts. Although in future research, we plan to perform such game-theoretic analysis to analyze community partnership decisions, this paper focuses on a simpler class of models in which for one participating organization, the behavior/decisions of other parties are known in a probabilistic sense. In this sense, our work can be classified as a game-against-nature formulation (Varian 1992). As shown in Section 4, we note that performing cooperative decision analysis is nontrivial and can deliver important insights as to why certain organizations behave as observed.

Option Pricing Models

Investing in community source can be viewed as a real option for potential future benefit. In recent years, the use of Real Options Analysis (ROA) to support IT investment decisions in various application settings has been investigated in MIS literature. There are different option pricing models such as Margrabe’s exchange option model, the Binomial model, the Black-Scholes (BS) model, and their extensions. One of the basic models for pricing financial options is the Black-Scholes model (Black et al. 1973, Hull 1993). It is widely used because of its simplicity. Benaroch and Kauffman (1999) examined the theoretical basis for applying option pricing model to IT evaluation. Moreover, they illustrated the feasibility of using the BS model to analyze a real deferral option. They argued that IT infrastructure projects may involve a “wait-and-see” component that directly follows the logic of ROA.

COMMUNITY SOURCE DEVELOPMENT: THE KUALI CASE

Kuali is a community source project to develop a comprehensive suite of administrative software that meets the needs of all Carnegie Class institutions (www.kuali.org). Kuali was started with migrating the Indiana University’s Financial Information System to a Web-based platform in 2004. Officially launched in August, 2004, the Indiana University and the University of Hawaii led the effort to build Kuali. In 2005, four new partners including the University of Arizona joined as core investors.
In July 2006, the University of California joined Kuali. There are currently seventeen development partners in the Kuali project.

There are two types of partners in Kuali: development partners and deployment partners. A development partner is one that has decided to pay a partnership fee to join in the development stage of the community source project whereas a deployment partner institution has decided to wait for the community source project to finish and then deploy the community source product. A deployment partner typically takes much longer to deploy Kuali than a deployment partner because of several reasons.

The reason for the Kuali project is that existing financial systems used in the universities are outdated and too difficult and time-consuming to maintain. The commercial academic ERP products are often excessively expensive and hard to customize; some institutions paid tens of millions to companies for software and installation, but still needed to build 15% of all the features to meet their specific financial transaction needs. On the other hand, building a financial system in house is equally daunting and can only be considered by the largest institutions. The Kuali project provides an attractive alternative to this “buy or build” dilemma. It pools institutional resources to develop an open source financial system, thus dramatically reducing the cost of managing fiscal data and processes in higher education.

Although the Kuali project got an award of $2.5M from the Andrew W. Mellon Foundation, it is mainly funded by member institutions. A Kuali development partner must pay from half million to one million dollar consisting of 25% cash and 75% personnel costs. Kuali uses a community source approach to allow member universities to share the cost for and the benefit from system development. To deploy the releases as open source, institutions who are not partners of the development community can become a member of the deployment community by paying about $25,000 per year to collaborate in the deployment and customization efforts. Of course, the organization can decide not to join any partnership and simply deploy the system for free.

In the context of Kuali, the community partnership decision leads to some interesting questions. Should a university decide to pay a hefty partnership fee in order to join the development community or simply wait for the open source application to be released to avoid the partnership fee? If the answer to the question is yes, when should they join? Although varying in detail, other community source projects have essentially similar management structure and thus the research insights gained on these questions are potentially generalizable.

DECISION ANALYSIS FOR INVESTMENTS IN COMMUNITY SOURCE

In this section, we will develop a formal model to analyze the community partnership decision. Since one institution’s decision will be affected by other institutions’ decisions, we apply a cooperative decision framework to investigate the interactions among institutions.

MODEL SETUP

To understand the rationale for an institution to join in a community source project as a paying developer partner, we first formalize various decisions available to this institute and their impact. For simplicity and ease of exposition, in our first modeling attempt, we assume that there are two players – institution A and institution B; both of them are engaged in the community source investment decision process. Each institution needs to decide if it is going to join as a development partner. Each can choose to play one of two strategies: join or not-join.

To develop an analytical model that captures the main elements of the real-world practice, we emphasize the external funding and open source in the community source model. In the traditional system collaboration model, institutions joining together to develop the system will not receive external funding and the resulting software will not open source. Under the community source environment, the situation is quite different. Institutions who join as development partners in community source can receive external funding and the system needs to be open source eventually (Table 1). We can see that in a community source project, once the institution joins as a development partner, the project could receive external funding from third-party sources such as a private foundation. Two institutions joining together to develop the project can help reduce the overall project risk and share the development cost. On the other hand, since the project will become open source eventually, the institution which decides not to join as a development partner can wait to adopt the software later on for free. In other words, the open source end result creates disincentive to join. Also the project risk will also make the institution to wait.

We make the following assumptions in our model to reflect these modeling considerations:

1. There are only two institutions, Institution A and Institution B, in the community. The community can be formed with one institution or two institutions.
2. The development partner needs to make an initial investment to the community. We assume a flat fee; the amount of the initial investments is fixed for all development partners.

3. There is an external funding source, a foundation, which will be contributing to the project. Under this assumption, the external funding is a benefit for the institution to join the community.

4. The system developed by the community will be open source eventually. Under this assumption, the institution who decides not to join as a development partner can wait to adopt the software when it becomes open source.

5. Success is very likely in the community source project. We ignore the possibility of failure in the community source development process to simplify the model. Models considering project failures are planned for future research.

6. Institution A knows a prior the possibility for institution B to join the community, $p_B$. Institution B knows the possibility for institution A to join the community, $p_A$. Information about $p_A$ and $p_B$ is common knowledge to both parties. This is a key assumption to simplify the model to make it tractable under the game-against-nature framework.

7. If Institution A (B) joins the community to develop the software and Institution B (A) does not join, Institution B (A) will wait until the software becomes open source. In reality, there might be other alternatives for Institution B (A). For instance, it might purchase a third-party software package or develops it in-house. Our model ignores such alternatives.

8. If both institutions choose not to join, they will develop the system individually.

9. Each of institution is trying to maximize the payoff when they make the decision for joining to be partner or not.

10. If both of the institutions choose to develop, Institution A gets payoff $PA_{11}$, Institution B gets payoff $PB_{11}$.

11. If both of the institutions choose to not to develop, there will be no software developed in this community. Institution A and Institution B will develop the system individually. They get payoff $PA_{22}$ and $PB_{22}$ respectively.

12. If Institution A chooses to join and Institution B chooses not to join, Institution A who join to develop gets payoff $PA_{12}$. Although Institution B does not join to develop at this stage, it can still adopt the software when the software becomes open source. So Institution B payoff is $PB_{12}$.

13. If Institution B chooses to develop and Institution A chooses not to develop, the payoff for Institution B is $PB_{21}$ and the payoff for Institution A is $PA_{21}$.

### Table 1. A Cooperative Analysis Framework.

<table>
<thead>
<tr>
<th>Institution A</th>
<th>Institution B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Partner</strong></td>
<td><strong>Not partner</strong></td>
</tr>
<tr>
<td>Institution A, Institution B</td>
<td>Institution A (joining, the CS)</td>
</tr>
<tr>
<td>* External Funding</td>
<td>* External Funding</td>
</tr>
<tr>
<td>* Open source</td>
<td>* Open source</td>
</tr>
<tr>
<td>(Both of institutions join the CS)</td>
<td>Institution B (waiting for open source)</td>
</tr>
<tr>
<td>$PA_{11}$, $PB_{11}$</td>
<td>* No external funding</td>
</tr>
<tr>
<td></td>
<td>* Open source</td>
</tr>
<tr>
<td></td>
<td>Institution B (joining the CS)</td>
</tr>
<tr>
<td></td>
<td>* External Funding</td>
</tr>
<tr>
<td></td>
<td>* Open source</td>
</tr>
<tr>
<td>$PA_{12}$, $PB_{12}$</td>
<td>$PA_{22}$, $PB_{22}$</td>
</tr>
<tr>
<td>Institution A (waiting for open source)</td>
<td>Institution A, Institution B</td>
</tr>
<tr>
<td>* No external funding</td>
<td>* No External Funding</td>
</tr>
<tr>
<td>* Open source</td>
<td>* No Open source</td>
</tr>
<tr>
<td>Institution B (joining the CS)</td>
<td>(Institution A and B develop the system individually)</td>
</tr>
<tr>
<td>* External Funding</td>
<td>* Open source</td>
</tr>
<tr>
<td>* Open source</td>
<td></td>
</tr>
</tbody>
</table>

### Payoff Analysis

As we can see above, there are four possible scenarios: institution A joining and institution B joining (AJ-BJ), institution A joining and institution B not joining (AJ-BN), institution A not joining and institution B joining (ANJ-BJ), institution A not joining and institution B not joining (ANJ-BN).
Table 2. Variables and Default Values.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Notation</th>
<th>Default value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_0 )</td>
<td>Base value for the system</td>
<td>$22m</td>
</tr>
<tr>
<td>( \mu )</td>
<td>Savings from the system per student</td>
<td>$50</td>
</tr>
<tr>
<td>( S_A, S_B )</td>
<td>The student number of institution A, institution B</td>
<td>10K, 50K</td>
</tr>
<tr>
<td>( I_0, I_0^* )</td>
<td>Community development initial investment, flexibility related part</td>
<td>$6m, $3m</td>
</tr>
<tr>
<td>( H_0, H_0^* )</td>
<td>Individual development initial investment</td>
<td>$4m</td>
</tr>
<tr>
<td>( D_0, D_0^* )</td>
<td>Initial deployment cost for joining the community or developing individually, flexibility related part</td>
<td>$0.1m, $0.05m</td>
</tr>
<tr>
<td>( D_1, D_1^* )</td>
<td>Initial deployment cost for taking open source result, flexibility related part</td>
<td>$0.3m, $0.15m</td>
</tr>
<tr>
<td>( E_0, E_0^* )</td>
<td>Initial maintenance cost for joining the community or developing individually, flexibility related part</td>
<td>$0.1m, $0.05m</td>
</tr>
<tr>
<td>( E_1, E_1^* )</td>
<td>Initial maintenance cost for taking open source result, flexibility related part</td>
<td>$0.3m, $0.15m</td>
</tr>
<tr>
<td>( \eta )</td>
<td>The size factor related to maintenance cost</td>
<td>50</td>
</tr>
<tr>
<td>( \sigma^2 )</td>
<td>Risk free rate, System variance, System flexibility rate</td>
<td>10%, 50%, 50%</td>
</tr>
<tr>
<td>( M )</td>
<td>Total amount of external funding</td>
<td>$0.5m</td>
</tr>
<tr>
<td>( \rho_A, \rho_B )</td>
<td>The probability of institution A joining, the probability of institution B joining</td>
<td>50%, 80%</td>
</tr>
<tr>
<td>( T_1 )</td>
<td>Application lasting time for joining the community</td>
<td>5 yrs</td>
</tr>
<tr>
<td>( T_2 )</td>
<td>Application lasting time for taking open source result</td>
<td>4 yrs</td>
</tr>
<tr>
<td>( T_3 )</td>
<td>Application lasting time for developing individually</td>
<td>3 yrs</td>
</tr>
</tbody>
</table>

In this study, we apply an option pricing model to decision making in community source investment. Past IS research has recognized that IT investments can embed various types of real options such as defer, stage, explore, alter operating scale, abandon, lease, outsource, and growth (Benaroch 2002). In a community source approach such as Kuali, there are different types of options a participating institution can choose, such as “become a development partner,” “wait and deploy Phase I,” “wait and deploy Phase II,” “expand,” “monitor,” and “abandon.”

Although the traditional NPV model has been extensively used in the past for investment analysis, it fails to take into account of various important real options relevant to IS development (Taudes et al. 2000). As such, option pricing models such as Black-Scholes and binomial have been adopted for IS investment analysis in various contexts (Benaroch et al. 1999).

In our study, the Black-Scholes model is chosen to calculate the institutions’ payoffs under different scenarios. This model was chosen largely because of its simplicity and wide application. The Black-Scholes model is shown below:

\[
BS = V_0N(d_1) - Xe^{-rT}N(d_2)
\]  

(1)

where \( d_1 = \frac{\ln(V/X) + (\rho^2/2)T}{\sigma\sqrt{T}} \) and \( d_2 = d_1 - \sigma\sqrt{T} \)

\( N(\cdot) \) is the cumulative standard normal distribution function, and \( d_1 \) and \( d_2 \) are used to determine the cumulative value of the distribution, which in turn affect the value of the asset.

The variables used in the cooperative analysis framework are listed in Table 2. The default values are also given in the table based on our observation of the Kuali case. We note that in our subsequent analysis, sensitivity analyses have been conducted to make sure that our main findings are not tied to specific values of these parameters.

We make the following assumptions to regarding the parameters in the Black-Scholes model while calculating the payoffs in four possible scenarios.
1. \[ V = V_0 + S \mu \]

We define system value \((V)\) is consisting of two parts: base value \((V_0)\) and size related value \((S\mu)\). Parameter \(S\) means the number of students in the university and \(\mu\) is the savings from the system per student.

2. \[ X = I + D + E \]

The cost \((X)\) is consisting of three parts: investment \((I)\), deployment cost \((D)\) and maintenance cost \((E)\). External funding \((M)\) can be considered as deduction of \(I\).

3. \[ I = I_0 + f\lambda \]

We assume that the initial investment increases if the system demands more flexibility. Investment \((I)\) is consisting of two parts: initial investment \((I_0)\) and flexibility related investment \((f\lambda I_0)\). Parameter \(\lambda\) is defined as the percentage of initial investment which is related to flexibility part.

4. \[ D = D_0 + \frac{D_\lambda}{T} \]

We assume that the deployment cost decreases when the system is more flexible. Deployment cost \((D)\) is consisting of two parts: initial deployment cost \((D_0)\) and flexibility-related deployment cost \((\frac{D_\lambda}{T})\). Parameter \(\lambda\) is defined as the percentage of initial deployment cost which is related to flexibility part. We assume that the initial deployment cost of institutions who participate in developing the system (joining the community or developing the system individually) is less than that of institutions who simply take the open source result.

5. \[ E = E_0 + \frac{E_\eta}{T} + \eta S \]

We assume that maintenance cost decreases when the system is more flexible. Maintenance cost \((E)\) is consisting of three parts: initial maintenance cost \((E_0)\), flexibility related maintenance cost \((\frac{E_\eta}{T})\) and size related maintenance cost \((\eta S)\). Parameter \(\eta\) is the size factor related to maintenance cost. The parameter \(\lambda\) is defined as the percentage of initial maintenance cost which is related to flexibility part.

We also assume that the initial maintenance cost of institutions who participate in developing the system (joining the community or developing the system individually) is less than that of institutions who simply take the open source result. \(T\) is defined as the system usage time in community source. \(T\) is affected by development time and deployment time. If the institution joins the community to develop the system, development time will be shortened with joint effort in development and the deployment time will be shortened either because of readily-available system customization and existing staff training. As such, the system application time under this situation is the longest. If the institution simply takes the resulting open source package without making any effort in development stage, the deployment time will be longer. If the institution develops the system individually, the development time is expected to be much longer than the community source approach.

6. \[ \rho \]

We define \(\rho\) as the probability vector of institute A and B joining in community source. We assume that \(\rho\) is common knowledge. Since the size of institution A is smaller than that of institution B, we believe that the probability of joining in community source for institution A is lower. We now present the payoff functions of institute A and B in these four possible scenarios.

Scenario 1: both Institution A and institution B join the community – \((AJ, BJ)\)

Under this scenario, Institution A and institution B receive external funding \(M\), divided equally between them to support development, for developing the system jointly.

The net payoff function for institution A in \((AJ, BJ)\) is as follows:

\[ PA_1 = BS_A = V_A N(d_{1,2}) - X_A e^{-\sigma T_1} N(d_{2,2}) \]

where \[ d_{1,2} = \frac{\ln(V_A/X_A) + (r + \sigma^2/2)T_1}{\sigma \sqrt{T_1}} \]
and \[ d_{2,2} = d_{1,2} - \sigma \sqrt{T_1} \]

\[ V_A = V_0 + S_A \mu, \quad X_A = I + D_A + E_A - M/2 \]
The net payoff function for institution B in (AJ, BJ) is as follows:

\[ PB_{1} = BS_{B} = V_{B} N(d_{1B}) - X_{B} e^{-r_{1}T_{2}} N(d_{2B}) \]

where \( d_{1B} = \frac{\ln(V_{B} / X_{B}) + (r + \sigma^{2} / 2)T_{2}}{\sigma \sqrt{T_{2}}} \) and \( d_{2B} = d_{1B} - \sigma \sqrt{T_{2}} \)

\[ V_{B} = V_{0} + S_{B} \mu, \quad X_{B} = I + D_{B} + E_{B} - M/2 \]

Scenario 2: Institution A joins the community but institution B does not – (AJ, BNJ)

Under this scenario, Institution A receives external funding M for developing the system. Institution B does not join and waits for the open source; the cost for institution B only includes the deployment cost and maintenance cost.

The net payoff function for institution A in (AJ, BNJ) is as follows:

\[ PA_{12} = BS_{A} = V_{A} N(d_{1A}) - X_{A} e^{-r_{1}T_{1}} N(d_{2A}) \]

where \( d_{1A} = \frac{\ln(V_{A} / X_{A}) + (r + \sigma^{2} / 2)T_{1}}{\sigma \sqrt{T_{1}}} \) and \( d_{2A} = d_{1A} - \sigma \sqrt{T_{1}} \)

\[ V_{A} = V_{0} + S_{A} \mu, \quad X_{A} = I + D_{A} + E_{A} - M \]

Scenario 3: Institution A does not join the community but institution B joins, simply denoted as (ANJ, BJ):

This scenario is symmetrical to Scenario 2.

The net payoff function for institution B in (ANJ, BJ) is as follows:

\[ PB_{12} = BS_{B} = V_{B} N(d_{1B}) - X_{B} e^{-r_{1}T_{2}} N(d_{2B}) \]

where \( d_{1B} = \frac{\ln(V_{B} / X_{B}) + (r + \sigma^{2} / 2)T_{2}}{\sigma \sqrt{T_{2}}} \) and \( d_{2B} = d_{1B} - \sigma \sqrt{T_{2}} \)

\[ V_{B} = V_{0} + S_{B} \mu, \quad X_{B} = D_{B} + E_{B} \]

\[ D_{B} = D_{1} + \frac{\mu_{0}}{\xi}, \quad E_{B} = E_{1} + \frac{\mu_{0}}{\xi} + \eta S_{B} \]

Scenario 3: Institution A does not join the community but institution B joins, simply denoted as (ANJ, BJ):

This scenario is symmetrical to Scenario 2.

The net payoff function for institution A in (ANJ, BJ) is as follows:

\[ PA_{12} = BS_{A} = V_{A} N(d_{1A}) - X_{A} e^{-r_{1}T_{1}} N(d_{2A}) \]

where \( d_{1A} = \frac{\ln(V_{A} / X_{A}) + (r + \sigma^{2} / 2)T_{1}}{\sigma \sqrt{T_{1}}} \) and \( d_{2A} = d_{1A} - \sigma \sqrt{T_{1}} \)

\[ V_{A} = V_{0} + S_{A} \mu, \quad X_{A} = D_{A} + E_{A} \]

\[ D_{A} = D_{1} + \frac{\mu_{0}}{\xi}, \quad E_{A} = E_{1} + \frac{\mu_{0}}{\xi} + \eta S_{A} \]

The net payoff function for institution B in (ANJ, BJ) is as follows:

\[ PB_{12} = BS_{B} = V_{B} N(d_{1B}) - X_{B} e^{-r_{1}T_{2}} N(d_{2B}) \]
where \( d_{1A} = \frac{\ln(V_A / X_A) + (r + \sigma^2 / 2)T_A}{\sigma \sqrt{T_A}} \) and \( d_{2A} = d_{1A} - \sigma \sqrt{T_A} \).

\[ V_A = V_0 + S_A \mu \cdot X_A = I + D_A + E_A - M \]

\[ I = I_0 + fJ_A \cdot D_A = D_A + \frac{\mu_{SA}}{\sigma} \cdot E_A = E_0 + \frac{\mu_{SA}}{\sigma} + \eta S_A \]

Scenario 4: Neither institution A nor institution B joins the community --- (ANJ, BNJ):

Under this scenario, both institutions choose to develop the system individually and the result is not open source.

The net payoff function for institution A in (ANJ, BNJ) is as follows:

\[ PA_{A2} = BS_A = V_A N(d_{1A}) - X_A e^{-\sigma^2 T_A} N(d_{2A}) \]

where \( d_{1A} = \frac{\ln(V_A / X_A) + (r + \sigma^2 / 2)T_A}{\sigma \sqrt{T_A}} \) and \( d_{2A} = d_{1A} - \sigma \sqrt{T_A} \).

\[ V_A = V_0 + S_A \mu \cdot X_A = H_0 + D_0 + E_0 + \eta S_A \]

The net payoff function for institution B in (ANJ, BNJ) is as follows:

\[ PB_{B2} = BS_B = V_B N(d_{1B}) - X_B e^{-\sigma^2 T_B} N(d_{2B}) \]

where \( d_{1B} = \frac{\ln(V_B / X_B) + (r + \sigma^2 / 2)T_B}{\sigma \sqrt{T_B}} \) and \( d_{2B} = d_{1B} - \sigma \sqrt{T_B} \).

\[ V_B = V_0 + S_B \mu \cdot X_B = H_0 + D_0 + E_0 + \eta S_B \]

The expected payoff for Institution A joining is \( EPAJ = \rho_A PA_{11} + (1 - \rho_A) PA_{12} \)

The expected payoff for Institution A not joining is \( EPANJ = \rho_A PA_{21} + (1 - \rho_A) PA_{22} \)

The expected payoff for Institution B joining is \( EPBJ = \rho_B PB_{11} + (1 - \rho_B) PB_{21} \)

The expected payoff for Institution B not joining is \( EPBNJ = \rho_B PB_{12} + (1 - \rho_B) PB_{22} \)

To gain further understanding of the community source investment decisions and study the relationship among various contributing factors, we have conducted a series of computational analysis through varying the values of some key parameters and observing the expected payoffs as given above. Figures 1-6 summarize our findings.

**Figure 1. Effect of Size on Expected Payoff for Institution A**

Figure 1 shows the effect of size on the expected payoff for institution A. As shown, there is a crossover point around 20,000 students. Before this point, the expected payoff for not joining is greater than that for joining. After this point, joining for institution A becomes a dominating strategy. More generally, we note that larger institutions are more likely to join the
community source than their smaller counterparts. Figure 2 shows the effect of \( S \) on the expected payoff for institution B. The trend in Figure 2 is similar to Figure 1. The difference is that the crossover point has moved up to 10,000 students.

Figure 3 and 4 show the effect of the deployment cost on the expected payoff for institution A and institution B, respectively. We can see that the expected payoff for not joining is greater than that for joining in Figure 3 while the expected payoff for joining is greater than that for not joining in Figure 4. This reinforces the observation that small-sized institutions are more likely not joining community source. We believe that an institution with a strong internal technology development team is more likely to have a reduced deployment cost. As this internal technology development capability decreases, the expected payoff for small institutions (Figure 3) decreases more rapidly than that for large institutions (Figure 4). Large institutions with strong internal capability are more likely to join the community source.

Figure 5 shows the effect of system flexibility on the expected payoff for institution A. On the lower end of the flexibility rate, there is a crossover point. When the flexibility rate is lower than the crossover point, the expected payoff for joining is greater than that for not joining. When the flexibility rate is higher than the crossover point, the expected payoff for not joining becomes dominating. When small size institutions are making the decision to join the community, they are pursuing certain degree of system flexibility which can reduce their deployment cost and maintenance cost without increased investment. Since high flexibility system requires high initial investment, small size institutions may choose to wait for open source to avoid huge initial investment. Figure 8 shows the effect of system flexibility on expected payoff for institution B. We can see that expected payoff for joining is always dominant no matter the degree of flexibility rate. Large institutions are more likely to join no matter the degree of flexibility rate.
Propositions:
Next we derive several propositions based on observing cooperative decision analysis with parameters large set based on the Kuali case.

Proposition 1. Larger institutions are more likely to join community source.

Discussion. It is shown in Figure 4, Figure 6 and Figure 8 that the expected payoff for institution B to join the development partnership is almost always dominant which strongly indicates that larger institutions are more likely to join community source. Since the number of students affects the system value, larger institutions can get more value of the system. The initial investment for a large institution is assumed to be the same as that for a small institution. Larger institutions usually have more financial resource, so the initial investment fee will be more affordable to larger institutions.

Proposition 2. Small institutions will be more likely to join if the system flexibility is low.

Discussion. There are two reasons for this behavior: First, when system requires more flexibility, initial investment will increase and deployment cost and maintenance cost will decrease. Lower system flexibility requires less initial investment, which can be afforded by small institutions. Second, lower system flexibility makes the option of waiting for the open source less attractive, which pushes small institutions to join the development partnership. Figure 7 clearly shows that the expected payoff for small institutions joined the development partnership is higher than that for small institutions not joined when the flexibility is at the lower end.

Proposition 3. The more internal development capability the institution has, the more likely it will become a development partner.

Discussion. We assume that institutions with more internal development capability can deploy the system with lower cost. As a result, expected payoff decreases when deployment cost increases (Figures 5 and 6). This is because higher deployment cost eats into the expected payoff. Note that although the decreasing trend of payoff is the similar, Figure 5 shows that smaller institutions turn not to join the development partnership and Figure 6 shows that larger institutions turn to join the development partnership.

CONCLUSIONS
In this paper, we investigated the institutional investment decisions in community source. Using cooperative decision analysis framework, we analyze decisions on whether or not an institution should invest in a community source. We derived several propositions based on the Kuali case and the results of a computational study based on both our analytical model and parameter setting derived from the Kuali case.

As we have shown in this paper, by becoming a development partner in the Kuali project, the institution can influence the application features, complete the deployment sooner, minimize the total cost of ownership, and reduce the variance of the system value. This incentive is the main driving force for institutions to make community source projects succeed.

There are two main limitations in this paper. First, the analytical model can be extended in several important directions. Current analysis involves only two institutions whereas often dozens of partners are present in community source projects. Relevant factors, such as project successful rate, are yet to be considered. Second, there are no empirical data so far to fully validate the propositions.

In future research, we will first collect empirical data to validate the propositions. A survey as well as interviews has been planned among partner institutions in Kuali. Second, in the current study, we assess the impact of individual factors. We plan to investigate the joint impact of multiple factors on investment decisions. Lastly, more sophisticated decision models (including game-theoretic ones) will be developed and evaluated.

REFERENCES